REPORT NO T16-90

THE EFFECTS OF SLEEP LOSS ON INDIVIDUAL AND GROUP PERFORMANCE

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

MAY 1990

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) T16-90	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION US Army Research Institute of Environmental Medicine	6b. OFFICE SYMBOL (If applicable) SGRD-UE-HP
7a. NAME OF MONITORING ORGANIZATION US Army Medical Research & Development Command	
6c. ADDRESS (City, State, and ZIP Code) Natick, MA 01760-5007	7b. ADDRESS (City, State, and ZIP Code) Ft. Detrick, Frederick, MD 21701-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Same as 6a.	8b. OFFICE SYMBOL (If applicable)
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS (City, State, and ZIP Code) Same as 6c.	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
61102A	3M1611-02BS15	CA	DA0C6122

11. TITLE (Include Security Classification)
The Effects of Sleep Loss on Individual and Group Performance

12. PERSONAL AUTHOR(S)
Robert H. Stretch and David W. Jamieson

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical Report	FROM ____ TO ____	1990 May	39

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Sleep Loss, sustained operations, performance

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This experiment was part of a study designed to assess the effects of two-hour naps on cognitive performance during sustained operation conditions. It was conducted using 12 young, military subjects who performed operations officer duties in a simulated brigade-level command post. They worked continuously processing military messages over a 4.5 day period and were tested on several recurring cognitive tasks. This paper reports the results of tasks and questionnaires assessing the effects of sleep loss on both individual and group performance. Across subjects, the results indicate significant sleep loss effects on perceived physical health, sleep quality, sleep value, and attributions of performance on mental tasks and individual and group cognitive performance. Significant individual differences in the effects of sleep loss are also noted. A discussion of the results is presented and it is asserted that there is a need to individualize the placement of naps in future studies to maximize performance.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Robert H. Stretch, MAJ, MS	22b. TELEPHONE (Include Area Code) 8-827-4101 x-2041 / 22c. OFFICE SYMBOL SGRD-UE-HP

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

THE EFFECTS OF SLEEP LOSS ON

INDIVIDUAL AND GROUP PERFORMANCE

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DISCLAIMER STATEMENT

The views, opinions, and/or findings in this report are those of the authors, and should not be construed as an official position, policy or decision of the United States Department of the Army or the Department of National Defence, Canada, unless so designated by other official documentation. Human subjects participated in these studies after giving their free and informed voluntary consent.

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EXECUTIVE SUMMARY

This experiment was part of a study designed to assess the effects of two hour naps on cognitive performance during sustained operation conditions. It was conducted using 12 young, military subjects who performed operations officer duties in a simulated brigade-level command post. They worked continuously processing military messages over a 4.5 day period and were tested on several recurring cognitive tasks. This paper reports the results of tasks and questionnaires assessing the effects of sleep loss on both individual and group performance. Across subjects, the results indicate significant sleep loss effects on perceived physical health, sleep quality, sleep value, and attributions of performance on mental tasks and individual and group cognitive performance. Significant individual differences in the effects of sleep loss are also noted. A discussion of the results is presented and it is asserted that there is a need to individualize the placement of naps in future studies to maximize performance.

KEYWORDS: Sleep loss, sustained operations, performance

INTRODUCTION

Combat doctrine for both NATO and WARSAW PACT forces emphasizes the need for around-the-clock capabilities. Soldiers must be capable of performing their missions during high-intensity operations lasting several days to weeks. Sleep will be a luxury that few soldiers will be able to afford except on a sporadic basis. Commanders, possibly through the use of sleep discipline strategies, must ensure efficient combat performance.

To this end, a series of studies has focused on estimating the effects of sustained mental work and sleep loss on a wide range of cognitive abilities within a command and control scenario (Angus and Heslegrave, 1985; Heslegrave and Angus, 1985). The basic findings have been that sleep loss results in performance decrements of approximately 25-30% during the first night without sleep (after about 18 hours on task), a plateau in peformance for 24 hours, and an additional decrement of 25-30% during the second night without sleep. Other researchers have also found decrements in mood and cognitive performance during periods of one or more nights without sleep (for reviews see Wilkinson, 1965, 1969a, 1969b; Naitoh, 1976; Johnson, 1982).

The use of naps (short periods of recovery sleep) as an aid to maintaining or recovering effective performance has been extensively studied. Longer naps generally have greater benefits to mood, performance, and alertness (Morgan, Brown, and Alluisi, 1974; Haslam, 1981), but nap placement within the circadian cycle may be as important as nap duration in terms of effectiveness (Naitoh, 1981; (Dinges, Orne & Orne, 1985).

The Defence and Civil Institute of Environmental Medicine (DCIEM) has investigated the effects on recovery from sleep loss of two hour naps given at various points in the circadian cycle. Recent experiments have focused on the effects of individual difference variables, sleep loss, and nap countermeasures on both individual and group performance (cf. Angus, Heslegrave, Pigeau & Jamieson, 1987).

This report describes the effects of a nap taken between 2200h and midnight (after 18 hours without sleep) on cognitive performance. Although the main purpose of the study was to determine if the nap served to maintain performance (i.e., prevent performance degradation) as was found in a similar study in which the nap was given at the same time of day after 40 hours without sleep (Angus, Heslegrave, Pigeau & Jamieson; 1987), this study also looked at the effects of sleep loss on a number of new tasks and questionnaires designed to measure individual and group performance. Statistics are reported from tasks developed to measure differences in perceived health, need for sleep, mood states, and cognitive performance.

METHODS

SUBJECTS

Twelve male, military subjects were recruited from Canadian Forces Base (CFB) Borden, a large training facility located approximately 60 miles north of the Metropolitan Toronto, Canada area. Subjects ranged in age from 18 to 26 (mean = 22.2 years) and received $125.00 for participating. All subjects volunteered for the study, were fully informed of the purpose and procedures, and understood that they were free to withdraw from the study at any time.

APPARATUS

The laboratory is a self-contained facility that is isolated from the normal activities of the building and can accommodate four subjects and several experimenters. Subjects were tested four at a time and worked individually in separate test rooms. Subjects were visually monitored by closed-circuit televisions and the information on each subject's terminal screen was displayed on slave monitors in a control area. Continuous EEG, ECG, facial EMG, and temperature data were recorded on Oxford Medilog ambulatory cassette recorders.

PROCEDURE

PROTOCOL

Subjects stayed in the laboratory for 4.5 days beginning Monday morning and continuing until Friday afternoon. After subjects arrived at the laboratory all time cues were removed and communication with the laboratory staff that was not directly related to the experiment was kept to a minimum. On Day 1 subjects were briefed or the scenario and given explanations of the military concepts, terminology, and procedures they would be exposed to during the experiment. The rest of the day was devoted to extensive training and practice on all tasks. During the evening, subjects were equipped for continuous physiological recordings. At 2200h subjects were allowed to sleep for an 8-hour period. The experiment began on Day 2 at 0800h. Subjects worked continuously until 2200h of Day 2 when they were given an unexpected two hour nap from 2200h-0001h. After the nap, subjects resumed working for 46 hours until 2200h of Day 4 (64 hours after the start of the experiment) at which time they were allowed to sleep for 8 hours. After this sleep, testing

resumed on Day 5 for an additional six hours to test for recovery effects. Subjects were then debriefed, paid, allowed to clean up, and transported back to CFB Borden. Figure 1 (see Appendix) presents a summary of the protocol.

EXPERIMENTAL DESIGN

The design comprised eleven six-hour blocks of identical cognitive tasks. Only the content of the military messages changed over the course of the experiment. Each of the eleven task blocks contained three 2-hour work sessions. Each session ended with a 15-minute break, during which subjects were permitted to eat, drink, use the restroom, or watch commercial videotapes of recent popular movies. The only exception was block 3, where a two hour nap was substituted for session 2.

The experimental tasks lasted from 5-15 minutes. A 15-minute "Scales and Battery" package was administered twice per work session, approximately once per hour at the beginning and again halfway through each 2-hour work session. This package comprised a variety of shorter tasks such as subjective scales, serial reaction time, logical reasoning, subtraction, and plotting. For a more detailed description of these tasks the reader is referred to Angus and Heslegrave (1985). Toward the end of each 6-hour block subjects gathered together in a separate room to perform a group interaction task which was monitored in the experimenter control area and videotaped. A typical 6 hour block of experimental activities is depicted in Figure 2 (see Appendix).

NEW TASKS/SCALES

The focus of the report is on new tasks and questionnaires used to look at individual and group performance in relation to the effects of sleep loss. With the exception of the Environmental Symptoms Questionnaire, all tasks and questionnaires described below were developed by the authors for use in this study.

Environmental Symptoms Questionnaire (ESQ). The ESQ was designed to obtain information about the incidence and severity of symptoms produced by exposure to several different climatic conditions (Kobrick and Sampson, 1979; Sampson, Cymerman, Burse, Maher, & Rock, 1983; Sampson and Kobrick, 1980). This 68 item questionnaire comprises nine factors: Cerebral AMS (Acute Mountain Sickness), Respiratory AMS, ENT (Ear, Nose and Throat discomfort), Cold Stress, Distress, Alertness, Exertion Stress, Muscular Discomfort, and Fatigue. For the present study the ESQ was modified to make it shorter and more appropriate for the measurement of sleep loss as a stressor. In this regard, the factors of Cerebral and Respiratory AMS, Cold Stress, and Exertion were eliminated. The resulting 45 item ESQ was administered to subjects once every three hours. Each item (e.g., "My muscles feel tight or stiff") was presented one at a time. The response categories remained on the subject's monitor until all 45 items were answered. The subject typed the number corresponding to the appropriate response which resulted in the next item automatically appearing on the screen. Responses included '0' (Not at all), '1' (Slight), '2' (Somewhat), '3' (Moderate), '4' (Quite a Bit), and '5' (Extreme).

Value of Sleep Questionnaire. This 10 item questionnaire was developed

for the study to determine how important the prospect of sleep becomes as sleep deprivation continues. Every six hours subjects were asked a series of questions relating to how sleepy they felt, how well they were performing both physically and mentally, and how much sleep they would need to perform as well as they did at the beginning of the experiment. Subjects were also asked whether they would take the opportunity to sleep now or save it for later if given the chance.

Performance Attribution Task. This seven item task, administered every six hours, asked subjects to determine the extent to which their performance on various cognitive tasks could be attributed to the following factors: mental ability, individual effort, personality, task difficulty, sleep loss, mood, perceived stress, and luck. Subjects were also asked questions designed to determine their motivation for continuing on with the study (e.g. *feel they have to, feel they should, really want to*).

Post-Sleep Inventory (PSI). The PSI is a 30 item questionnaire developed to determine the subject's retrospective perceptions of their physical and emotional state upon going to sleep, during sleep, and upon waking. The PSI was administered three times during the study: after waking prior to the actual start of the study, after the two hour nap, and after the recovery night sleep.

General Information Task. At approximately one hour intervals, subjects were presented with a set of five questions. These questions were designed to assess the subject's knowledge in several different areas such as history, geography, science, literature, sports, and music. All questions had been selected from a larger pool of questions after having been previously rated by four judges on level of difficulty. Items

judged to be too difficult for potential subjects (young, male military members) were excluded. Each question was presented on the subject's screen. Subjects typed in their answers and hit the "Return" key to advance the next question. All questions were designed to be answered in a few short words.

Individual Induction Task. Once during each six hour block subjects were presented with a series of five sets of five words or short phrases. Within each set, the five words or phrases were related to each other. The subject's task was to discover what that relationship was and type it on the screen. After typing the answer the subject hit the "Return" key which advanced the next set. These sets were of three basic types. In the first type, each of the five words or phrases represented examples of a category or other descriptive term. For example, "Logan", "Hood", "Shasta" , "McKinley" and "St. Helens" are all mountains. In the second type, all five words or phrases describe or are related to an object, person, place or concept. For example, "hot buttered rum", "chestnut", "bobsled", "freeze" and "frost" are all things associated with winter. The third type consisted of words which could be paired with a common word to create new words. For example, "shot", "board", "wheat", "eye" and "skin" can be combined with the correct answer, "buck", to produce buckshot, buckboard, buckwheat, buckeye, and buckskin. As with the General Information Task, all stimuli had been previously rated by four judges on difficulty level with the most difficult items from the original, larger pool eliminated.

Group Induction Task. At the end of every six hour block, all subjects were gathered together in a separate room to complete the Group Induction Task. This task consisted of the same format as the Individual Induction

Task except that it was completed using paper and pencil and was done in a group setting. The group was presented with five numbered envelopes, each containing a piece of paper with five related words or phrases. The object of the task was for the group of subjects to come up with the answer which was then written down on the paper, placed in the envelope, and sealed. All tasks were done in order. During this time the subjects, who were seated at a table, were recorded using a video camera positioned in the room and a VCR and monitor in the experimenter control area so that the group interaction could be analyzed later to investigate the effects of sleep deprivation on small group dynamics.

RESULTS

SELF-REPORT DATA

ESQ. ESQ data were examined to determine which symptoms appear to be sensitive to sleep loss. On the basis of items which were marked as not being experienced by subjects over 90% of the time, the ESQ was reduced in size from 45 items and nine factors to 30 items and five factors. These factors include ENT, Distress, Alertness, Muscular Discomfort, and Fatigue. Data for the Alertness factor were recoded according to the recommendations in Shukitt, Banderet & Sampson (1990). Separate analyses of variance (ANOVAs) were conducted for each scale of the revised ESQ to determine whether sleep loss had an effect. Figure 3 (see Appendix) shows data for the scale Fatigue. As can be seen, subjects became increasingly more fatigued during the periods of sleep deprivation as indicated by higher scores ($F[21,2608] = 14.12$, $p < 0.001$). The results of Duncan's Multiple Range Tests (alpha=0.05 level of significance) indicate that, following a slight (but nonsignificant) recovery after the nap, fatigue increased significantly until 0830h, showed a significant

recovery at 1430h, and then increased significantly, reaching a peak at around 0530h on the third morning. A second significant recovery occurred at 1430h. Fatigue then increased significantly until the subjects were allowed to sleep. Following the recovery night sleep, fatigue was not significantly different from baseline levels.

The effect of the two hour nap from 2200h to midnight the first evening appears to be one of delaying the expected increase in fatigue rather than preventing the initial increase in fatigue that has been documented in previous sleep loss studies (Angus & Heslegrave, 1985). While such previous studies have shown the initial increase in fatigue to occur around 0600h, in the present study this increase was delayed several hours.

Similar patterns (with some fluctuations) were also found for the scales Distress ($F[21,1819] = 3.75$, $p < 0.001$), Alertness ($F[21,767] = 14.62$, $p < 0.001$), Muscular Discomfort ($F[21,1293] = 3.93$, $p < 0.01$), and ENT ($F[21,1293] = 2.08$, $p < 0.01$) as shown in Figures 4-7 (see Appendix). The pattern for Alertness appears to be reversed due to the fact that lower, rather than higher, scores are associated with decreased levels of alertness.

The frequency with which subjects were bothered by various symptoms in the ESQ was assessed by tallying the number of times responses other than "Not at all" were made and dividing by the total number of administrations. The following are the most commonly cited symptoms (the figure in parentheses is the frequency with which subjects cited being bothered by the symptoms): having a headache (32%), feeling sinus pressure (32%), feeling weak (40%), backache (40%), irritated eyes (49%), feeling tired (68%), feeling sleepy (73%), feeling irritable (56%),

concentration off (74%), feeling restless (64%), and feeling bored (79%).

Value of Sleep Questionnaire. Data from this questionnaire were analyzed using ANOVAs to determine the effects of sleep loss on subject responses to the 10 items in the questionnaire. The data confirm that subjects felt progressively sleepier across the course of the study ($F[10,121] = 10.65$, $p < 0.001$), and felt that their overall mental performance, in general, ($F[10,121] = 6.76$, $p < 0.001$) and their logical reasoning task (LRT) performance, in particular, ($F[10,121] = 9.95$, $p < 0.001$) became progressively worse over the course of the study. When asked how much sleep they would need to keep from feeling overly tired or sleepy, estimates increased steadily across the study ($F[10,121] = 5.73$, $p < 0.001$). When asked about their mental performance if they were allowed to sleep for the amount of time they specified they needed to keep from feeling overly tired or sleepy, subjects indicated their mental performance would improve over the course of the study ($F[10,121] = 5.77$, $p < 0.001$).

Subjects were asked to specify the amount of sleep they would need to be able to perform as well mentally as they did at the beginning of the study. This amount of time increased steadily ($F[10,121] = 6.69$, $p < 0.001$). When asked how they would feel physically if given the amount of sleep they specified to improve their mental performance, subjects indicated they would feel better over the course of the study ($F[10,121] = 2.28$, $p < 0.05$). Subjects' estimates of the importance of sleep increased over the course of the study for both physical ($F[10,121] = 5.19$, $p < 0.001$) and mental ($F[10,121] = 8.43$, $p < 0.001$) performance. When asked if, given the opportunity, they could sleep now or save it for later, subjects were significantly more likely to say they would take it

now as the study progressed ($F[10,121] = 6.18$, $p < 0.001$). Figures 8-17 (see Appendix) present the data patterns for each item. As can be seen, the patterns are remarkably similar to those presented for the ESQ data. Again, the effect of the nap appears to be one of delaying the expected negative effects of sleep loss by several hours. The overall pattern is one of an increase in negative effects following the first night, a plateau for approximately 24 hours, and a further increase in negative effects following the second night.

Among subjects, however, there is a great deal of variability in the effects of sleep loss on their answers. With the exception of item 9 (How important would it be for your mental performance to get some sleep right now?), there were highly significant differences between subjects for all answers. Results of ANOVAs yielded F values significant at $p < 0.01$ for seven items and $p < 0.05$ for two items. Thus, although all subjects were affected by sleep loss, the perceived degree to which they were affected differs considerably.

Performance Attribution Task. The Performance Attribution questionnaire was analyzed by ANOVAs to detect changes in how subjects attributed their performance on various tasks across the course of the experiment. Subjects were asked to rate, on a scale of 0-100% with 100% being the best possible performance, their overall performance in the last six hours on all mental performance tests compared to what they thought they were capable of achieving. As can be seen in Figure 18 (see Appendix), subjects' estimates of their performance changed significantly across the experiment ($F[9,110] = 6.07$, $p < 0.001$) with a large drop occurring the morning of Day 2, slight but nonsignificant recovery, and a second large drop occurring the morning of Day 3.

When asked to what extent various factors influenced their performance on the Logical Reasoning Task during the past six hours, initially subjects stated that their mental ability and the difficulty of the mental tasks had the greatest influence on their performance, followed by how hard they tried, their personality, their mood, how stressed they felt, luck (good or bad), and loss of sleep. The only factor which changed in importance over the course of the study was loss of sleep ($F[9,110] = 8.53$, $p < 0.001$). Figure 19 (see Appendix) shows the pattern of a generally steady increase in importance of loss of sleep on subjects' attributions of their performance on all mental tasks. No significant differences across time were found for subjects' continuing on in the experiment because they felt they really had to continue, felt they should continue, or felt they wanted to continue.

Post-Sleep Inventory. The PSI was administered three times over the course of the experiment: the morning following the training day, following the two hour nap from 2200h to midnight the first day of the experiment, and following the recovery night sleep the morning of Day 4. Results of ANOVAs revealed significant differences at the $p < 0.05$ level for seven items: "I had a good sleep", "I fell asleep quickly", "I felt very sleepy when I went to bed", "I felt bad physically when I went to bed", "I felt exhausted when I went to bed", "While in bed I woke up frequently", "While in bed I slept lightly". One other item, "I woke up and got out of bed feeling bad physically" approached significance ($F[2,33] = 2.99$, $p = 0.06$).

Duncan's Multiple Range Test was performed on the means for these items to interpret the significant differences identified in the ANOVA procedures. Results indicate that subjects rated the sleep during the

recovery night ($M = 3.83$) as being significantly better than during the nap ($M = 2.83$, $MSE = 1.07$, $p < 0.05$); they reported falling asleep significantly faster during the recovery night ($M = 4.00$) than during either the nap ($M = 1.92$) or the training night ($M = 1.92$, $MSE = 2.18$, $p < 0.05$); they felt significantly sleepier when they went to bed during the recovery night ($M = 3.08$) than during the nap ($M = 1.08$) or the training night ($M = 1.75$, $MSE = 2.55$, $p < 0.05$); they felt worse physically when they went to bed during the recovery night ($M = 2.00$) than for the nap ($M = 0.25$) or the training night ($M = 0.25$, $MSE = 1.29$, $p < 0.05$); they felt significantly more exhausted when they went to bed during the recovery night ($M = 3.08$) than for the nap ($M = 0.42$) or the training night ($M = 0.25$, $MSE = 1.12$, $p < 0.05$); while in bed, however, they woke up significantly more frequently during the training night ($M = 2.50$) than either the nap ($M = 0.33$) or the recovery night ($M = 0.50$, $MSE = 1.24$, $p < 0.05$); subjects also slept significantly more lightly during the training night ($M = 2.17$) than either the nap ($M = 1.08$) or the recovery night ($M = 0.41$, $MSE = 1.32$, $p < 0.05$); subjects woke up and got out of bed feeling significantly worse physically after the recovery night ($M = 2.17$) than after the training night ($M = 0.83$, $MSE = 1.18$, $p < 0.05$).

PERFORMANCE DATA

General Information Task. The General Information Task was scored by totalling the number of questions answered correctly (maximum = 5) during each presentation. Highly significant differences were found in subject performance across time ($F[54,604] = 3.85$, $p < 0.001$). For ease of presentation, the data from the five administrations of the task within each block were averaged. One exception is block 3 in which the data

were averaged for the two administrations of the task occurring before the nap and three after the nap. These data are presented in Figure 20 (see Appendix). Results of Duncan's Multiple Range Test indicate a significant ($p < 0.05$) increase in performance after the nap followed by a sharp decrease in performance around 0900h the morning of Day 2. Performance then increased significantly during the afternoon and steadily dropped until the early morning of Day 3 at which time a significant recovery occurred.

Individual Induction Task. For this task, a subject's score consisted of the number of sets of words or phrases they succeeded in solving correctly, with a range of 0-5. Results of an ANOVA revealed that there were significant changes in subject performance across the course of the experiment ($F[10,121] = 2.45$, $p = 0.01$). Figure 21 (see Appendix) shows a sharp rise in performance after the nap followed by a sharp decline the morning of Day 2. For this task, the nap appears to have had a significant beneficial effect on performance as well as delaying the negative effects of sleep loss by several hours.

Group Induction Task. The Group Induction Task data were scored and analyzed in the same manner as the Individual Induction Task. Results of an ANOVA also revealed significant changes in subject performance over time ($F[10,33] = 3.48$, $p < 0.01$). Figure 22 (see Appendix), however, shows a different pattern in that performance also increased sharply during the afternoon and evening of Day 2 and, following a significant decrease during the early morning, also increased steadily during the afternoon and evening of Day 3.

One of the purposes of the Group Induction Task was to provide a means for group interaction among subjects. It was hoped that performance on the task would depend upon how well the members worked together as a group such that the "whole is greater than the sum of the parts". Comparisons between performance on the group and individual tasks suggests that this is indeed the case. Overall performance on the Group Induction Task ($M = 4.09$) was significantly greater than performance on the Individual Induction Task ($M = 2.68$, $t = 4.97$, $p < 0.001$). To look at differences in performance over time, a comparison of group and individual performance on the induction task was made for the nine times (out of eleven) when these two tasks were completed within one hour of each other. Testing the differences between the means at these times revealed that group performance was significantly better ($p < 0.05$) than individual performance on six of nine occasions. At no time was the average individual performance greater than group performance.

Further support for the hypothesis of beneficial effects of group work can be inferred from the results of Pearson Correlations between individual performance and group performance on these two tasks, which revealed no significant relationship ($r = -0.27$, $p = 0.42$). Thus, how well subjects perform this task as individuals is not predictive of how well the group performs this task. The group performance is, on average, better than individual performance.

DISCUSSION

The results presented in this report demonstrate that sleep loss has significant effects on measures of self-reported physical health, the quality of subsequent sleep following periods of deprivation, subjects'

perceptions of their performance on various mental tasks, and their actual performance on different mental tasks, both within a group and individual context. Of particular importance is the finding concerning the effects of the two hour nap on subsequent performance. Previous work using this same experimental paradigm found that a two hour nap given at the same time of day (2200h - midnight) on the second night of the study (following 40 hours of sleep loss) served to maintain performance at the pre-nap level (Angus, Heslegrave, Pigeau & Jamieson; 1987).

In the present study, however, the two hour nap given at the same time of day following 18 hours of sleep loss did not maintain performance at the pre-nap level. It did, however, seem to delay by several hours the expected low point in performance which usually occurs around 0600. This may be due to the greater time between testing (one or two data collection points each six hours) for many of the tasks presented in this report as compared to past tasks. It may also be that subjects were not sufficiently tired to fall asleep quickly and receive the maximum benefit from the nap. In a future report results of tests of these hypotheses will be presented using data from more frequently measured cognitive tests and EEG data recorded during the nap.

The results presented in this report also underscore the importance of sleep loss on individual subjects rather than groups of subjects. The results of the Value of Sleep Questionnaire point out the significant variation in subject's perceived need for sleep at various points throughout the study. When asked if they would take sleep now or save it for later, several subjects indicated they felt they needed to take sleep starting with Block 4 (roughly 20 hours into the experiment) and continued to respond this way throughout the rest of the experiment.

Other subjects, however, responded throughout the experiment that they did not need to take sleep now, while others indicated they felt they needed to sleep only one or two times throughout the experiment. Rather than simply giving all subjects a nap at the same time, these results indicate the need to give subjects a nap at the time that is best for them in terms of their own performance. Results of additional analyses examining the relationship between subjects' perceived need for sleep and their actual performance will be presented in a future report.

The finding that group performance on the induction task is significantly better over time than average individual performance on the induction task has several important implications for military operations. One is that decisions made within the context of a group are less likely to be negatively affected by sleep deprivation due, presumably, to individual differences in the effects of sleep loss on cognitive performance. Those individuals in the group who are affected the least by sleep loss at various points in time should be able to exert a rational, moderating influence on the decision-making process by recognizing proposed decisions by others in the group that may be ill-conceived or not well-thought out due to sleep loss.

A second implication stemming from this finding is that sleep discipline strategies should be implemented which ensure that there is at least one person in the group at all times who is relatively fresh and able to recognize poor decisions. These proposals necessarily require that commanders be willing to submit their proposed decisions to a group consensus process and be willing to accept recommendations made by the group for different decisions. This may not be a popular course of action for many military commanders who are unwilling to delegate

authority, but it may be these same commanders who consider themselves too important to sleep during sustained operations and end up making poor decisions as a result.

More research is needed to establish the link between sleep loss and individual vs. group performance on aspects of the decision-making process other than the induction task described in this report. If this link can be demonstrated, then additional efforts can focus on trying to improve decision-making under sustained operations conditions by modifying commanders' attitudes toward sleep discipline and group consensus of decisions.

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APPENDIX

RESULTS OF TASK/QUESTIONNAIRE ANALYSES

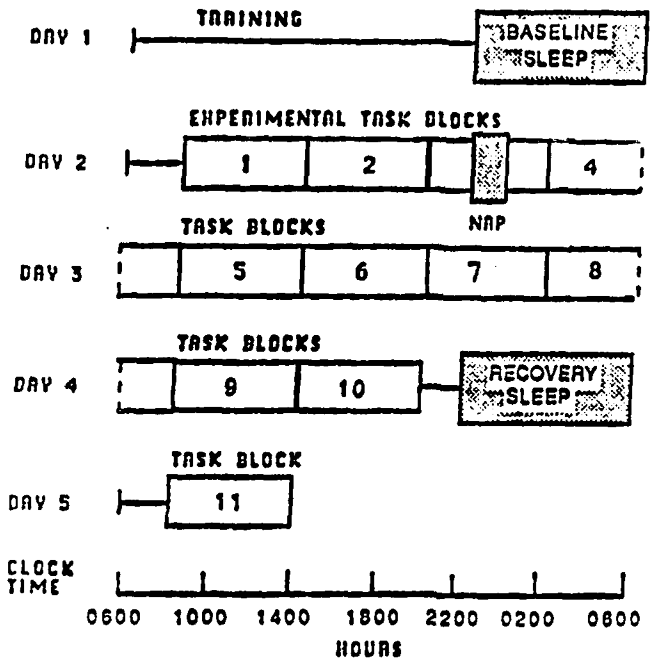


FIGURE 1. Experimental Design

Outline of design for an experiment investigating the effects of a 2-hour nap between 2200h-0001h.

6 HOUR BLOCK

TIME	TASKS	
HOUR ONE	SCALES TIME ESTIMATION MESSAGES ESQ GENERAL INFORMATION STRESS AROUSAL INDIVIDUAL INDUCTION ENCODING/DECODING MESSAGES	SESSION ONE
HOUR TWO	SCALES TIME ESTIMATION ARITHMETIC MESSAGES SLEEPVALUE GENERAL INFORMATION BREAK	
HOUR THREE	SCALES TIME ESTIMATION SERIAL REACTION TIME GENERAL INFORMATION MESSAGES COMPLEX SUBTRACTION MESSAGES	SESSION TWO
HOUR FOUR	SCALES TIME ESTIMATION MESSAGES PERFORMANCE ATTRIBUTION LOGICAL REASONING GENERAL INFORMATION BREAK	
HOUR FIVE	SCALES TIME ESTIMATION MEMORY TRAINING MESSAGES GENERAL INFORMATION MESSAGES	SESSION THREE
HOUR SIX	SCALES TIME ESTIMATION MESSAGES PLOTTING MEMORY RECALL GROUP INDUCTION BREAK	

Figure 2. Temporal sequence of experimental activities within each 6 hour block

Figure 3. ESQ Scale = Fatigue

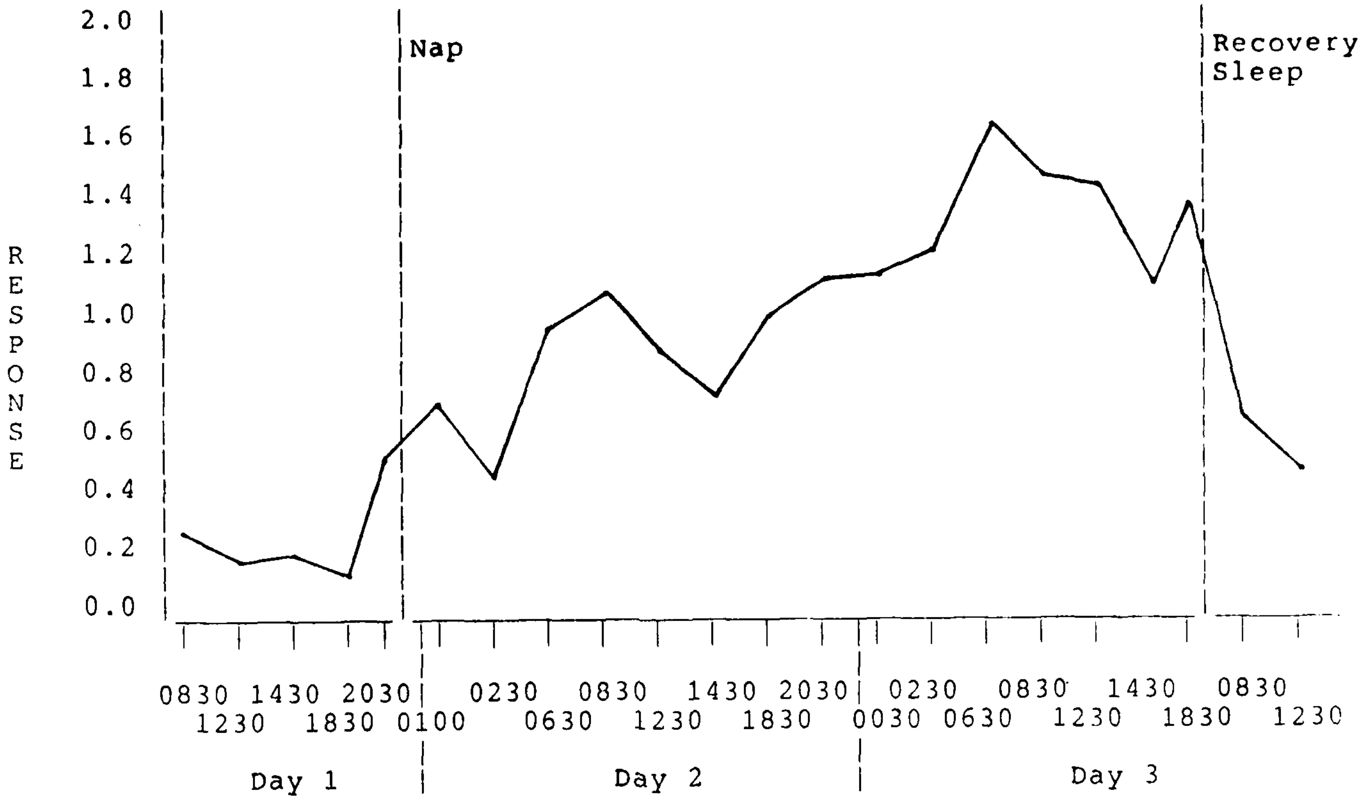


Figure 4. ESQ Scale = Distress

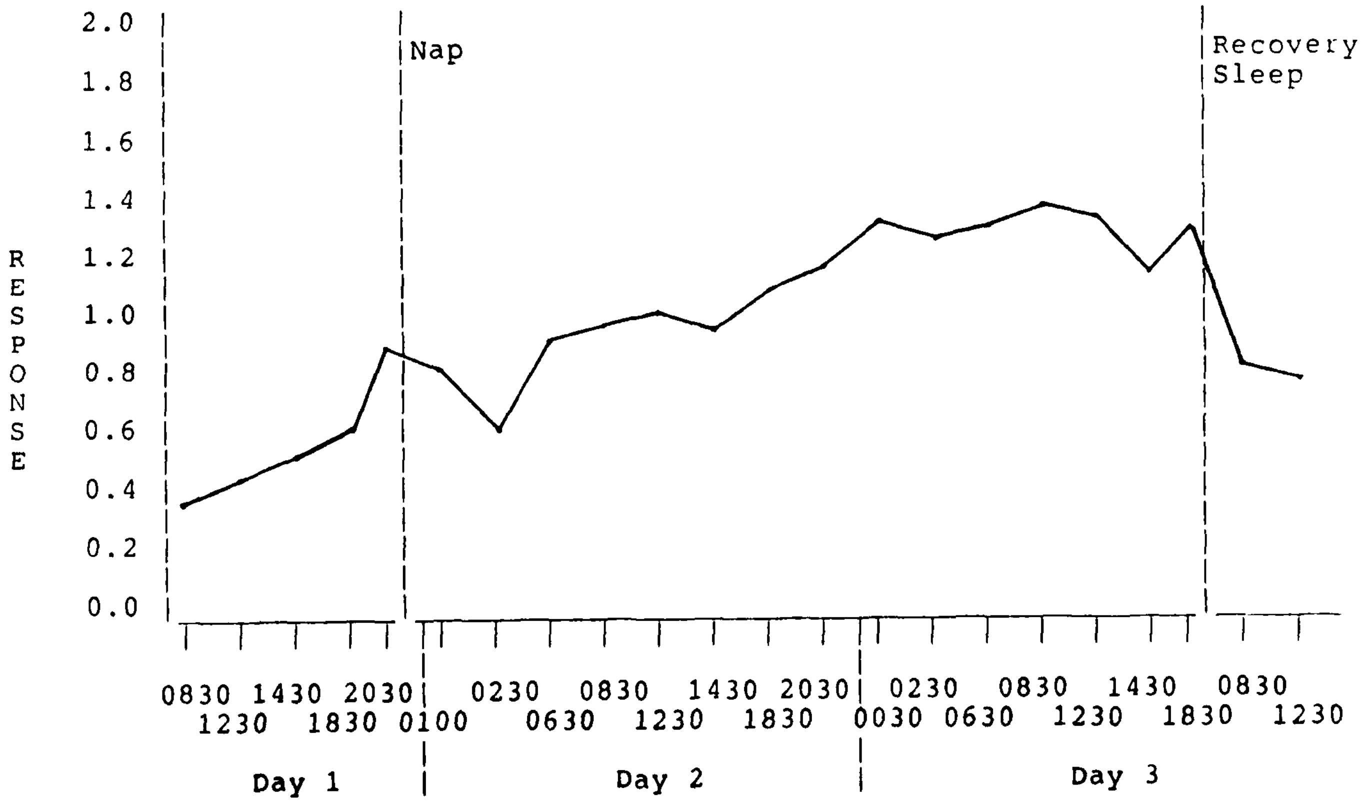


Figure 5. ESQ Scale = Alert

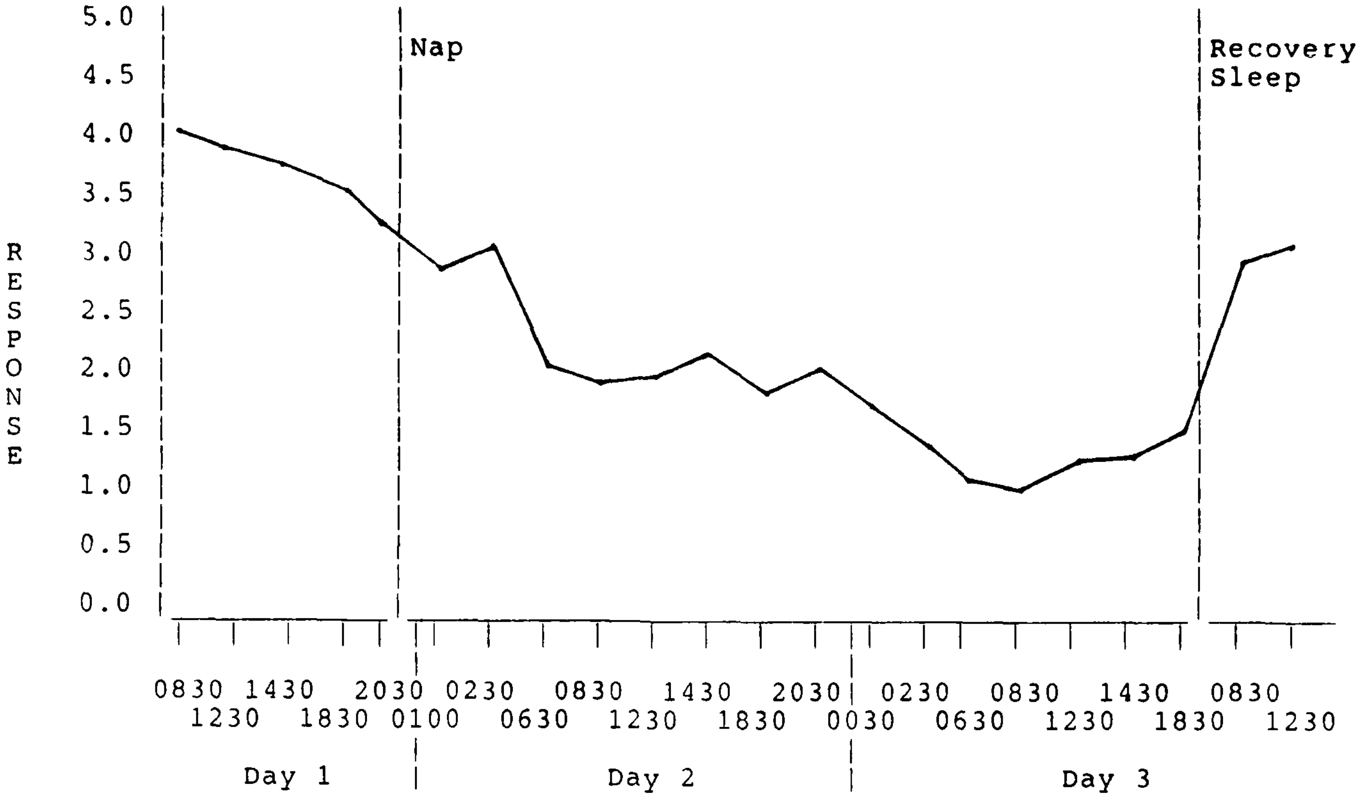


Figure 6. ESQ Scale = Muscular Discomfort

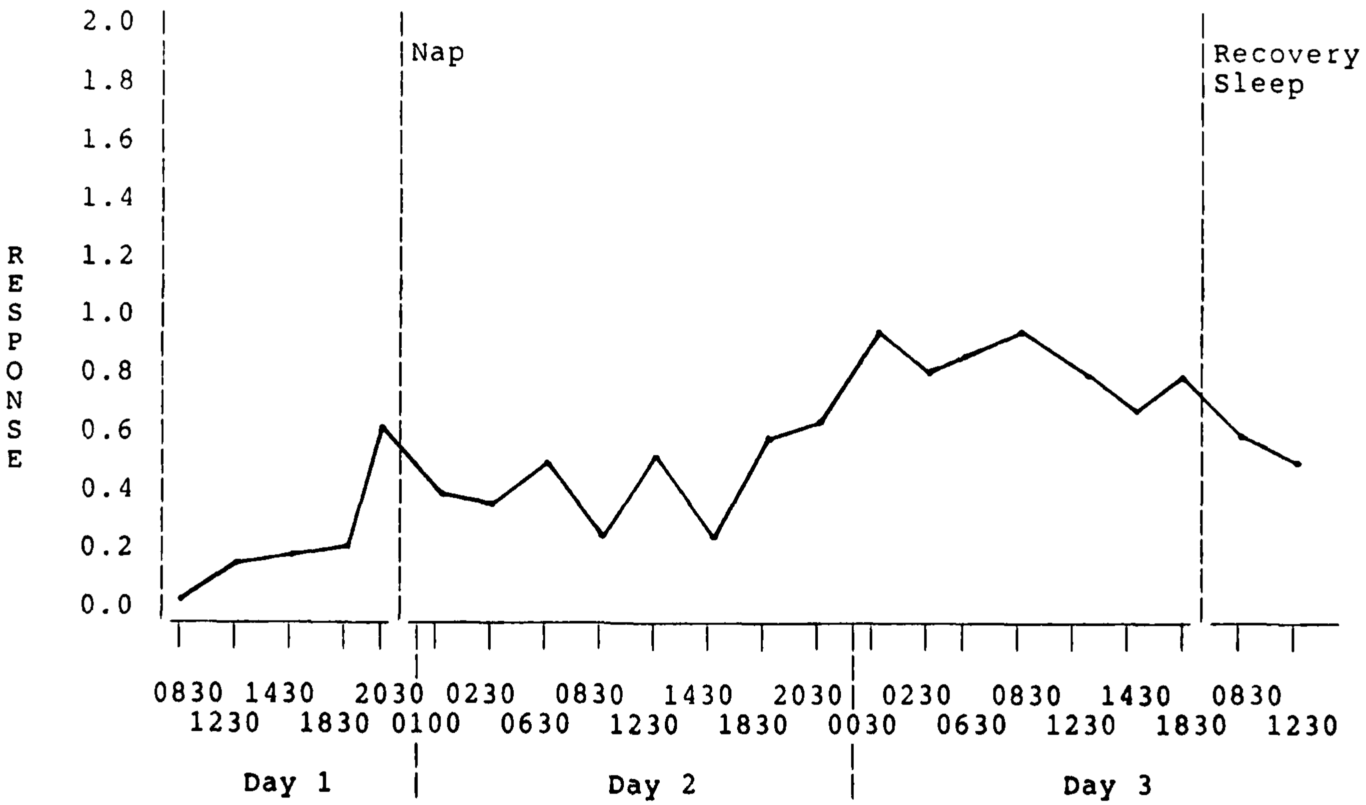


Figure 7. ESQ Scale = ENT

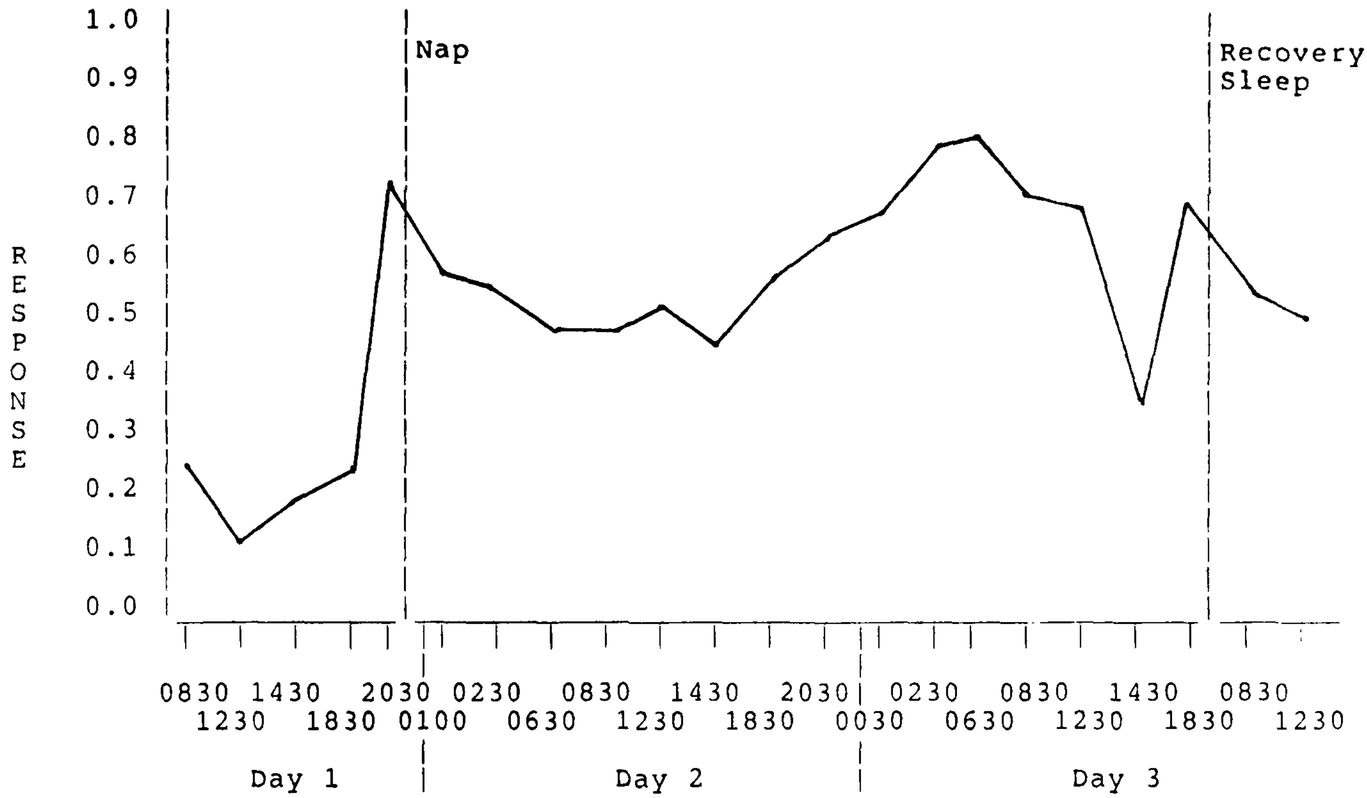


Figure 8. Sleep Value: Estimate for Current Sleepiness

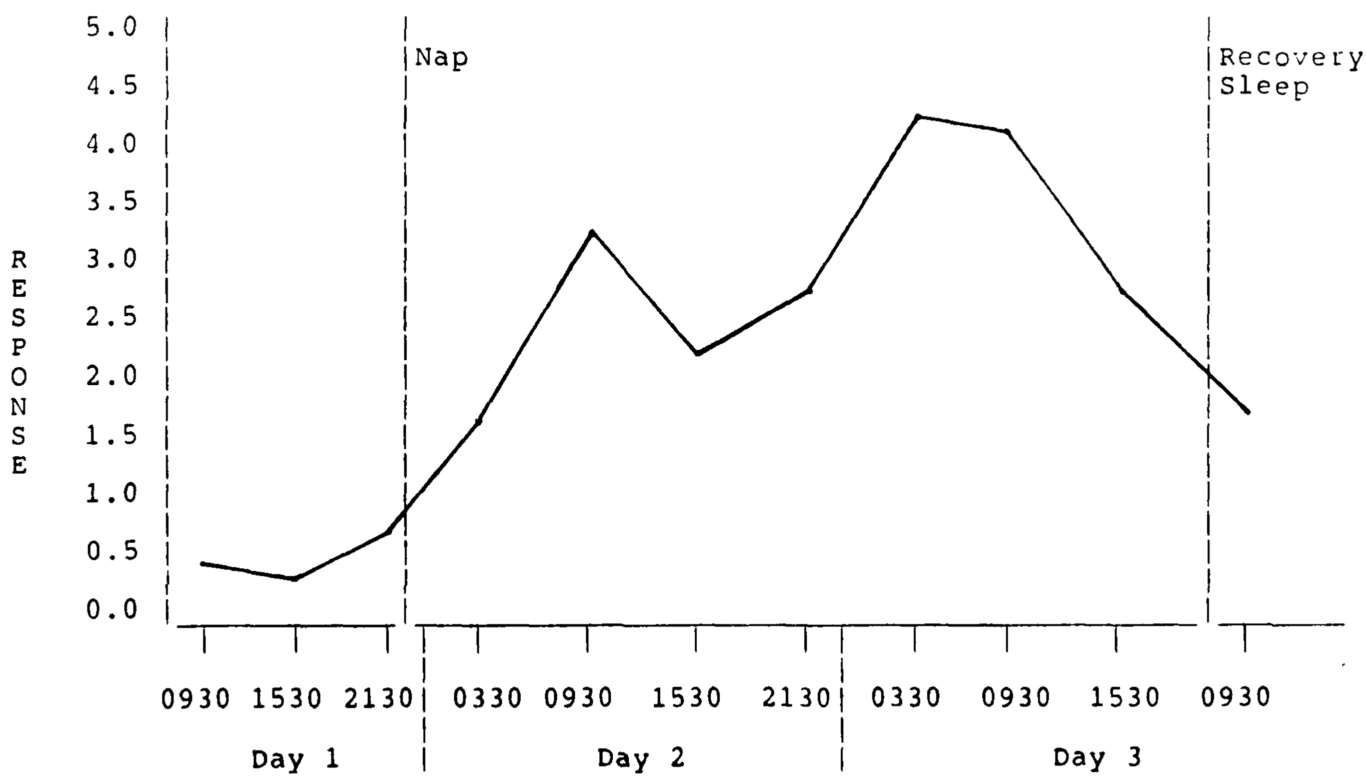


Figure 9. Sleep Value: Estimate of Overall Mental Performance

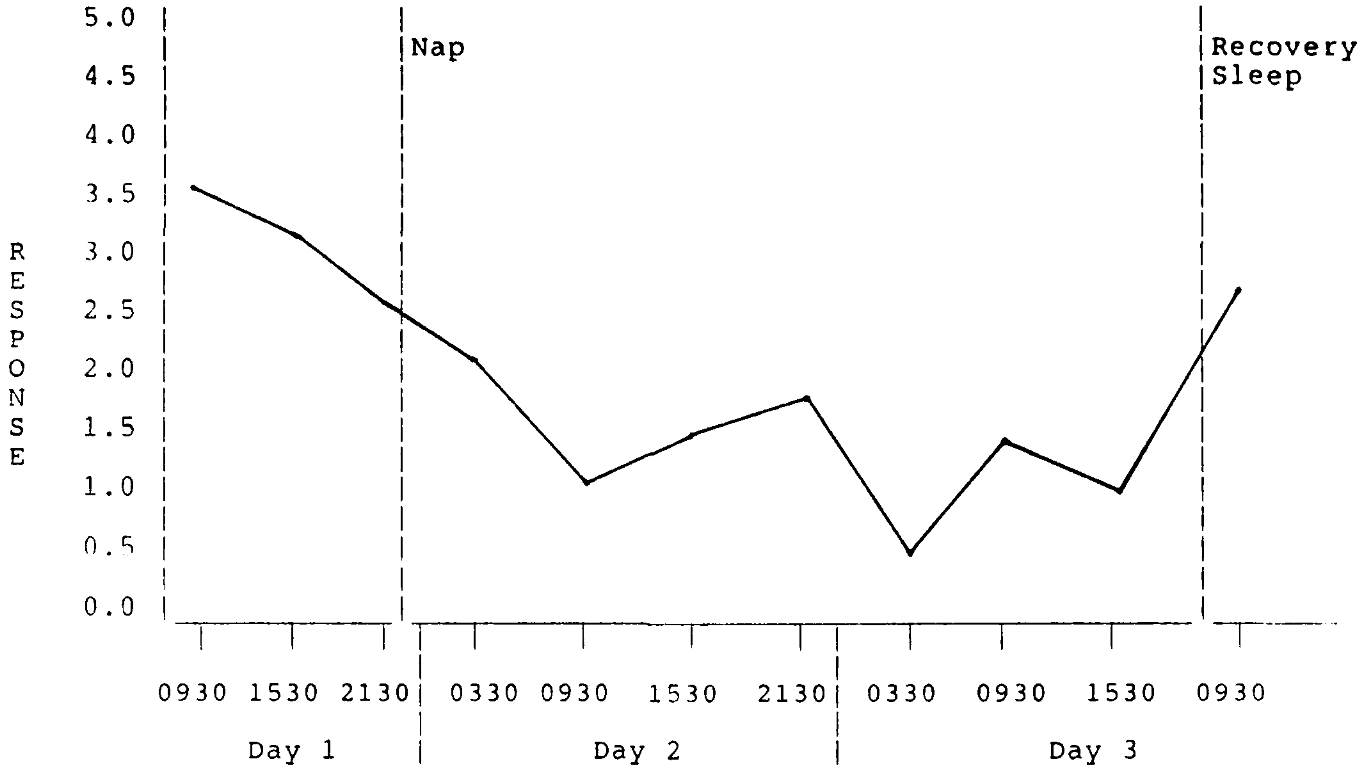


Figure 10. Sleep Value: Estimate of Performance on LRT

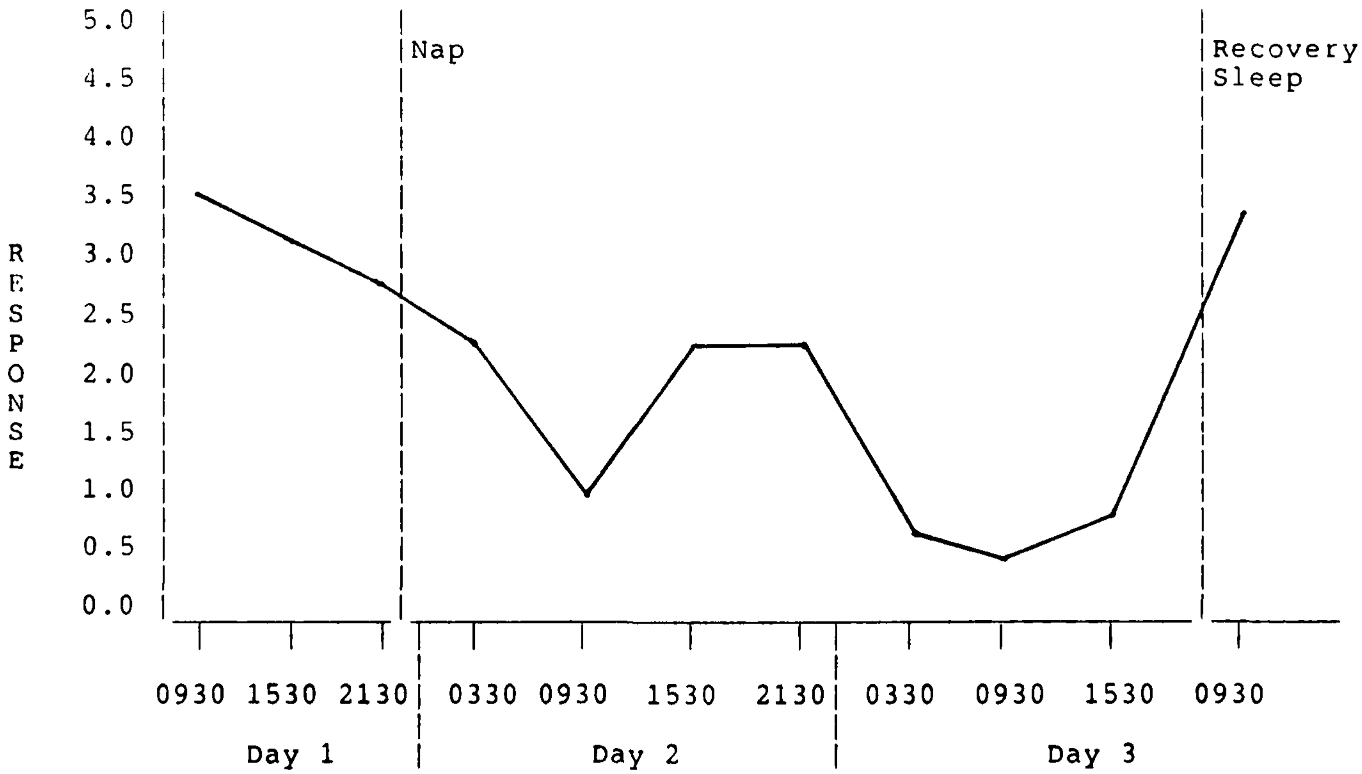


Figure 11. Sleep Value: Current Estimate of Sleep Required

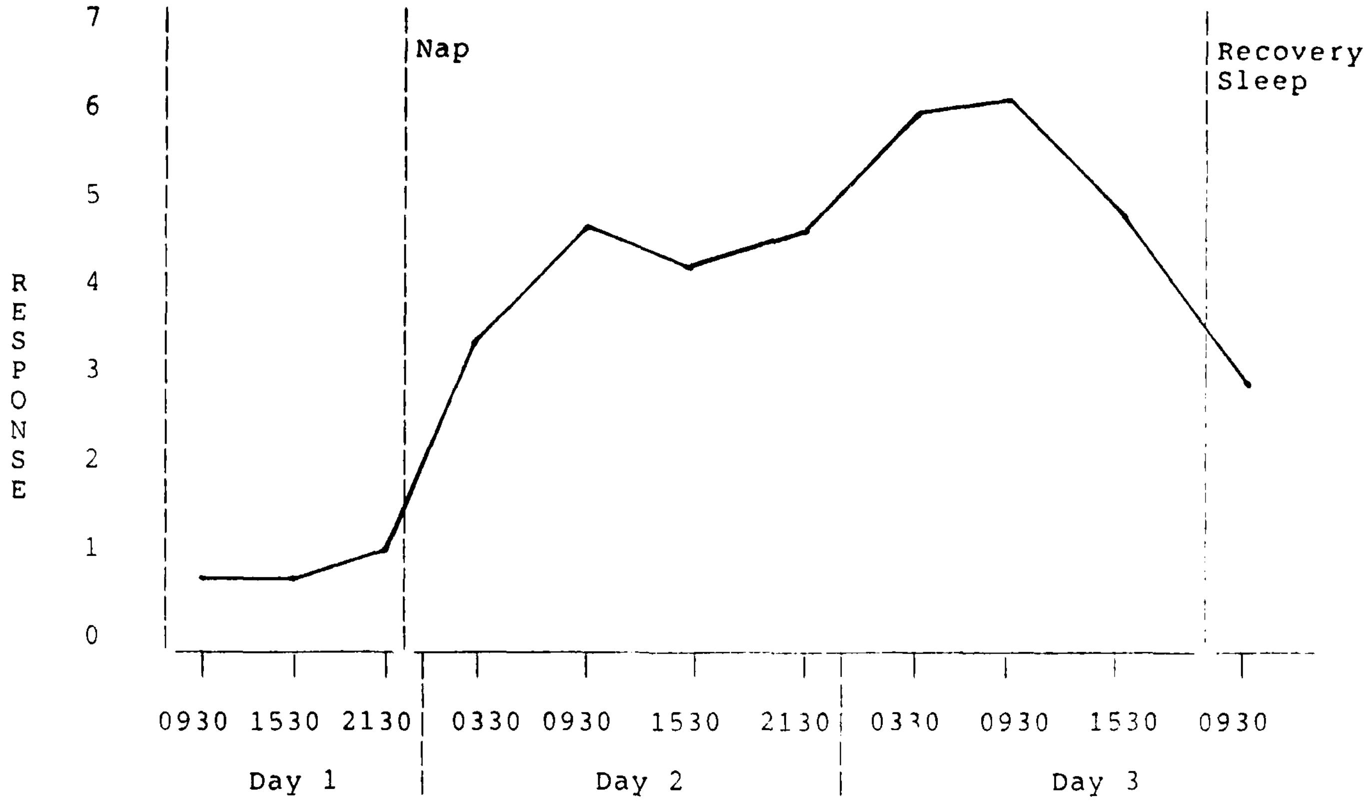


Figure 12. Sleep Value: Estimate of Performance if Given Sleep Desired

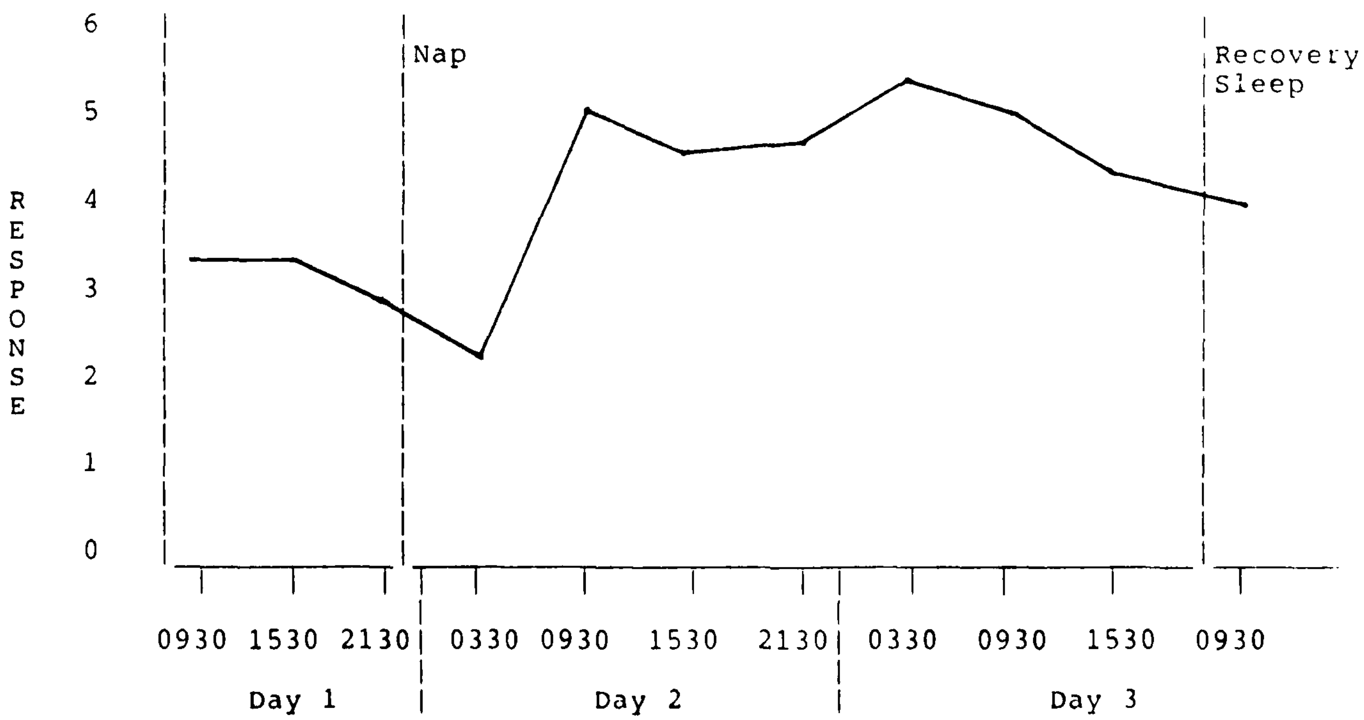


Figure 13. Sleep Value: Least Amount of Sleep Needed for Mental Performance

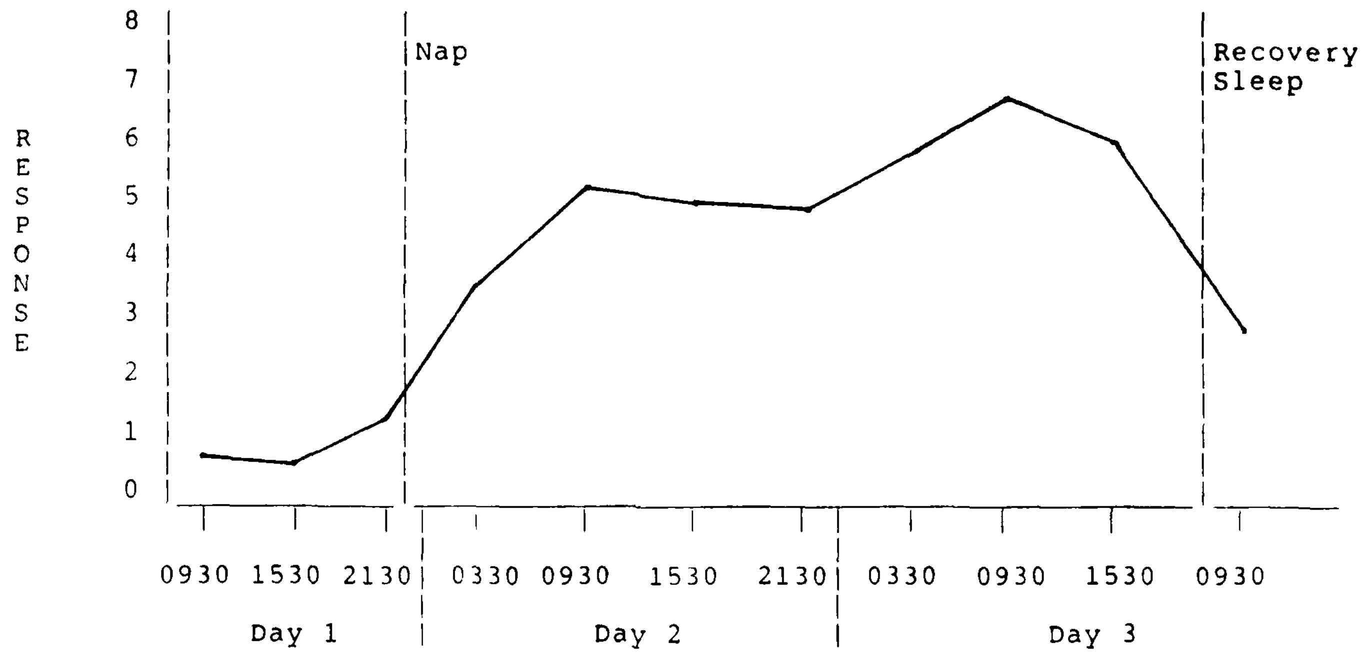


Figure 14. Sleep Value: Effects on Physical State if Given Desired Sleep

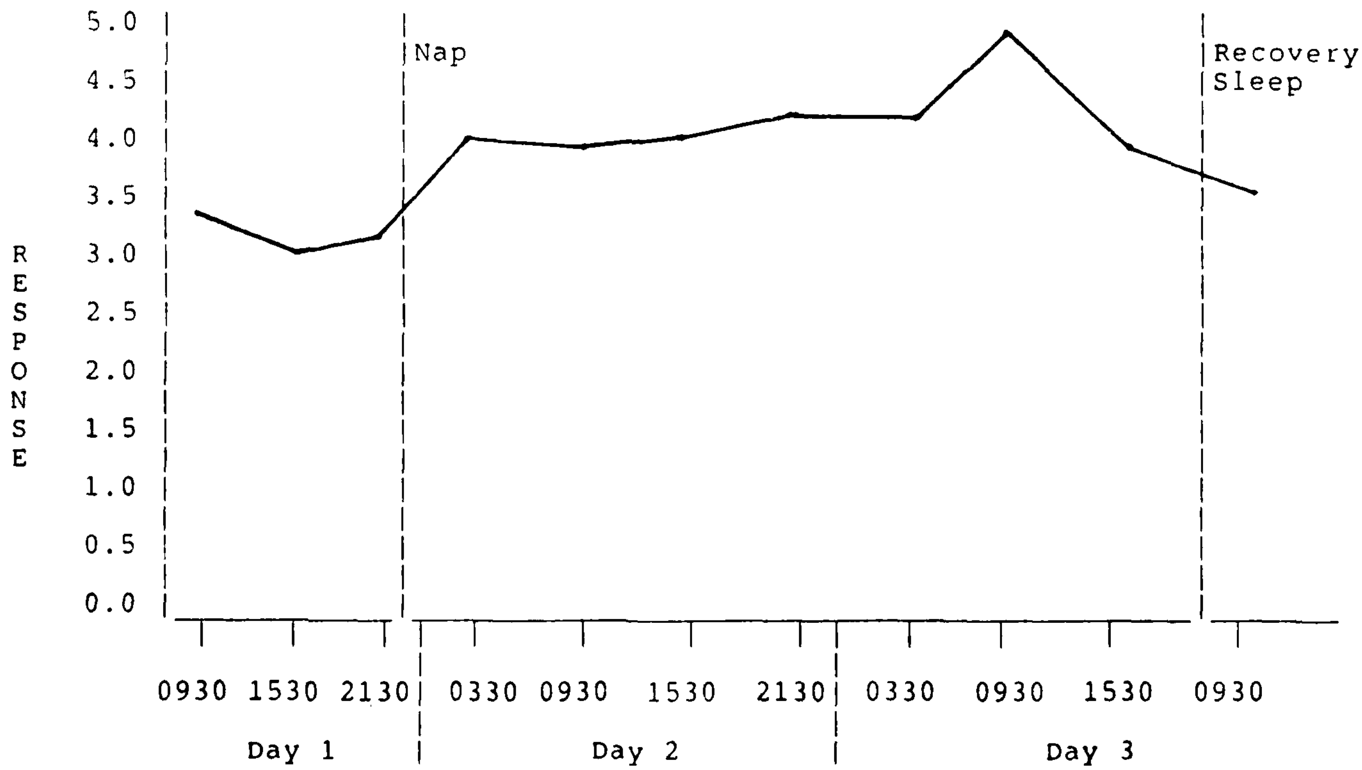


Figure 15. Sleep Value: Estimate of Current Physical Need for Sleep

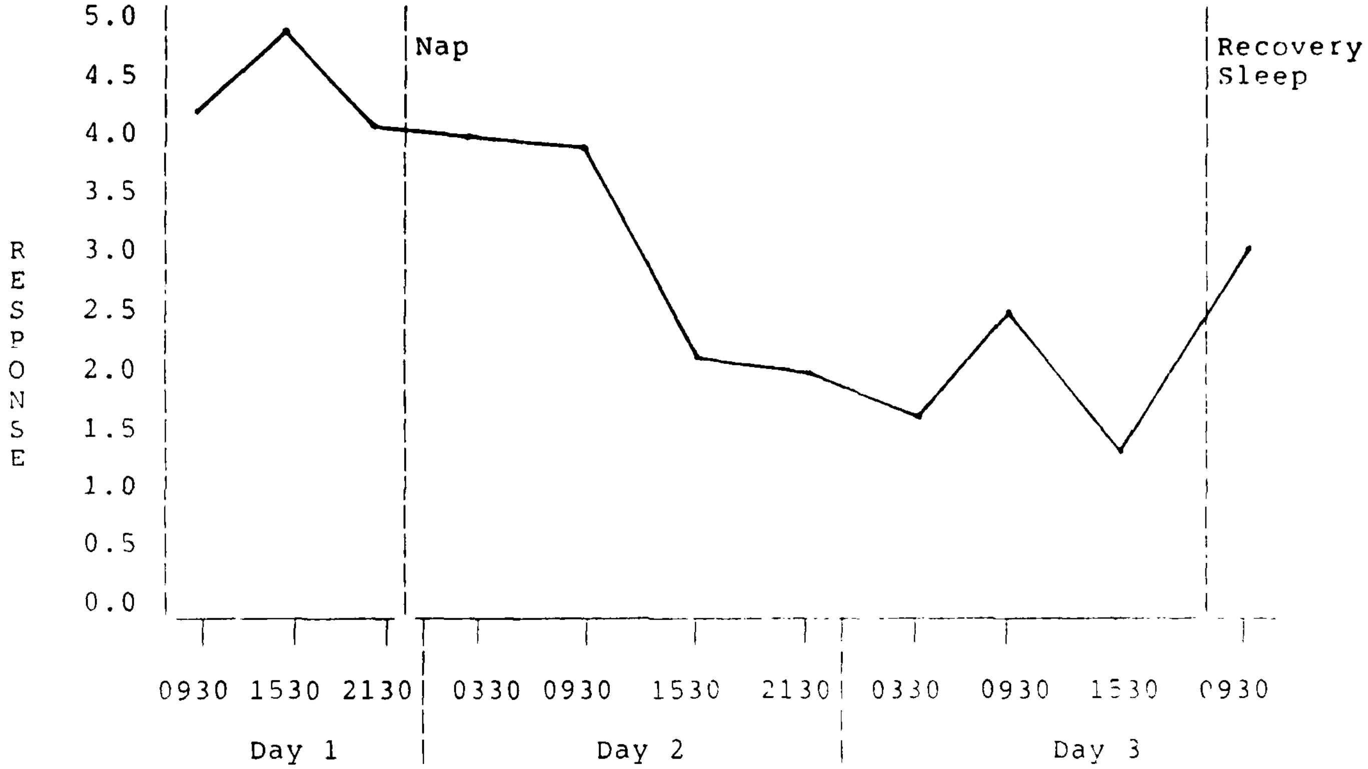


Figure 16. Sleep Value: Estimate of Current Mental Performance Need for Sleep

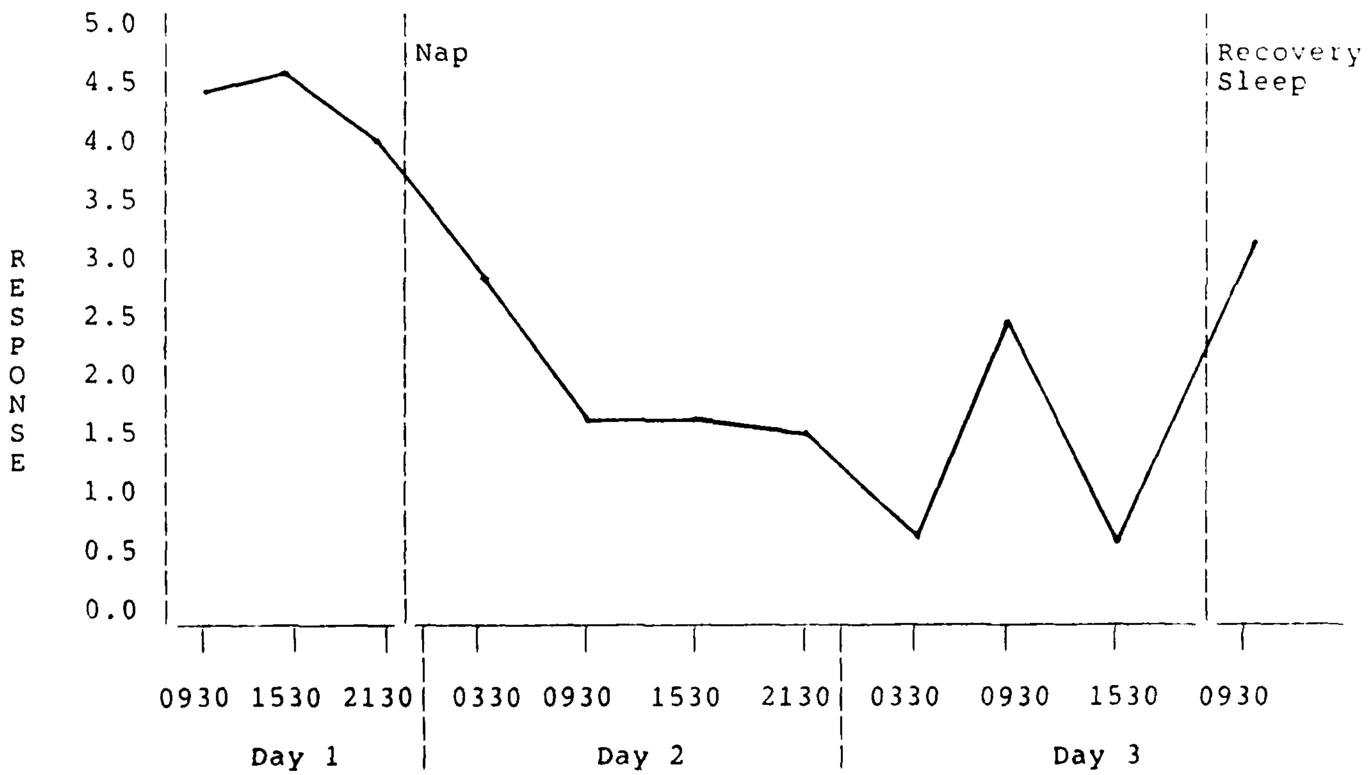


Figure 17. Sleep Value: Desire to Take Sleep Now or Take it Later

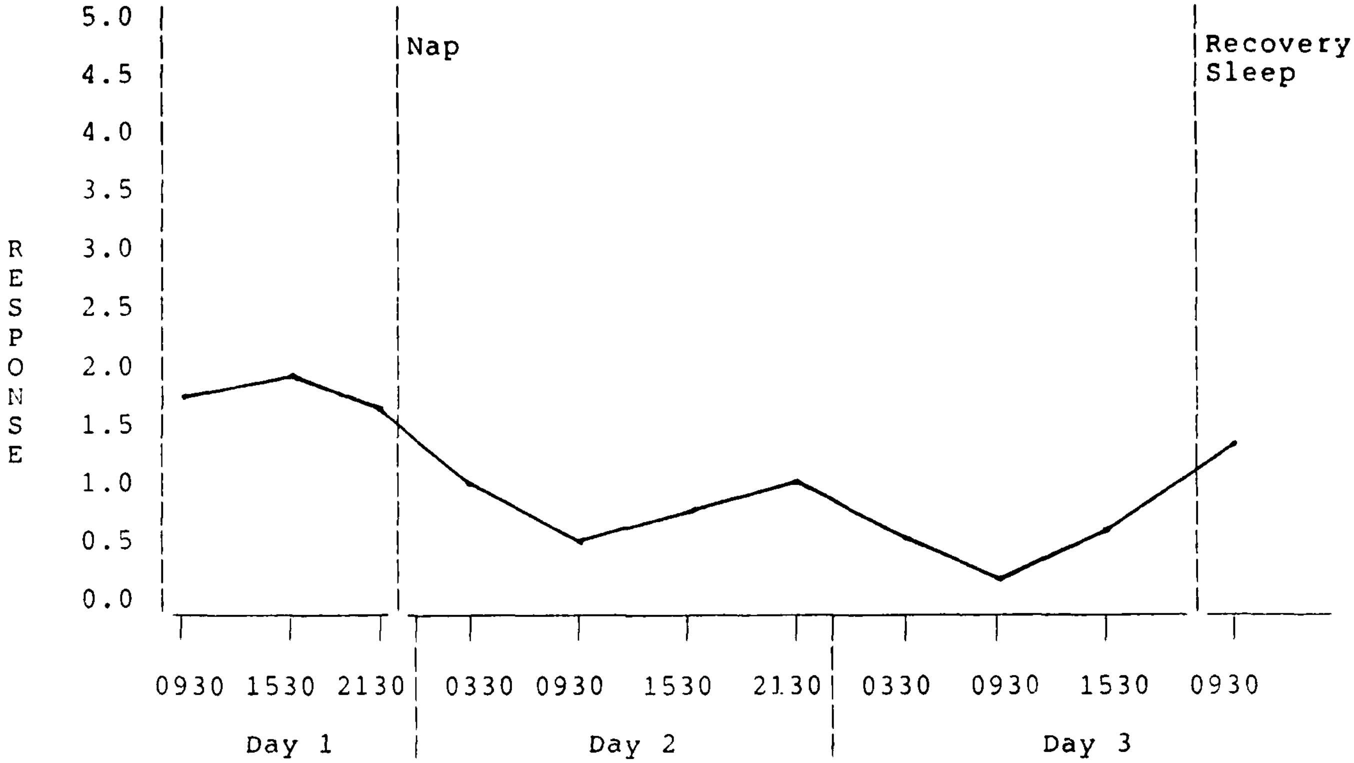


Figure 18. Performance Attribution: Performance Estimates for all Mental Tests

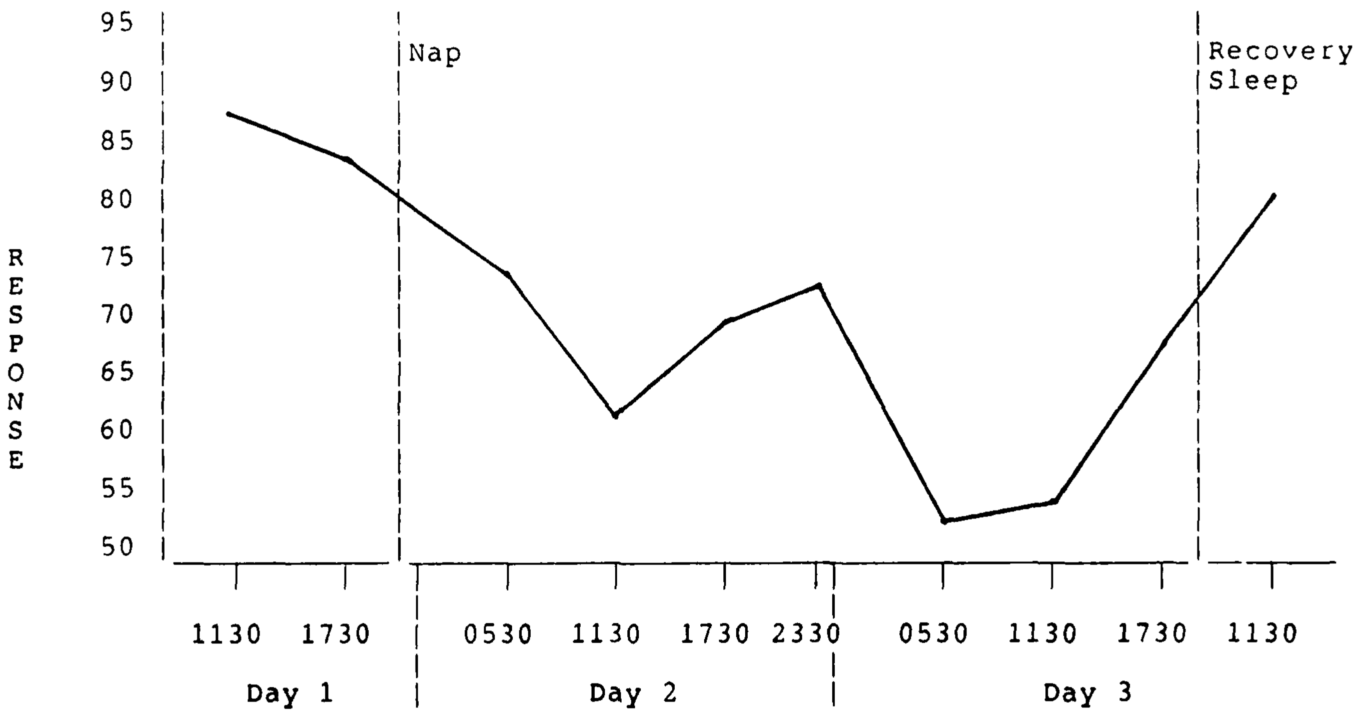


Figure 19. Performance Attribution: Effects of Sleep Loss on All Mental Tests

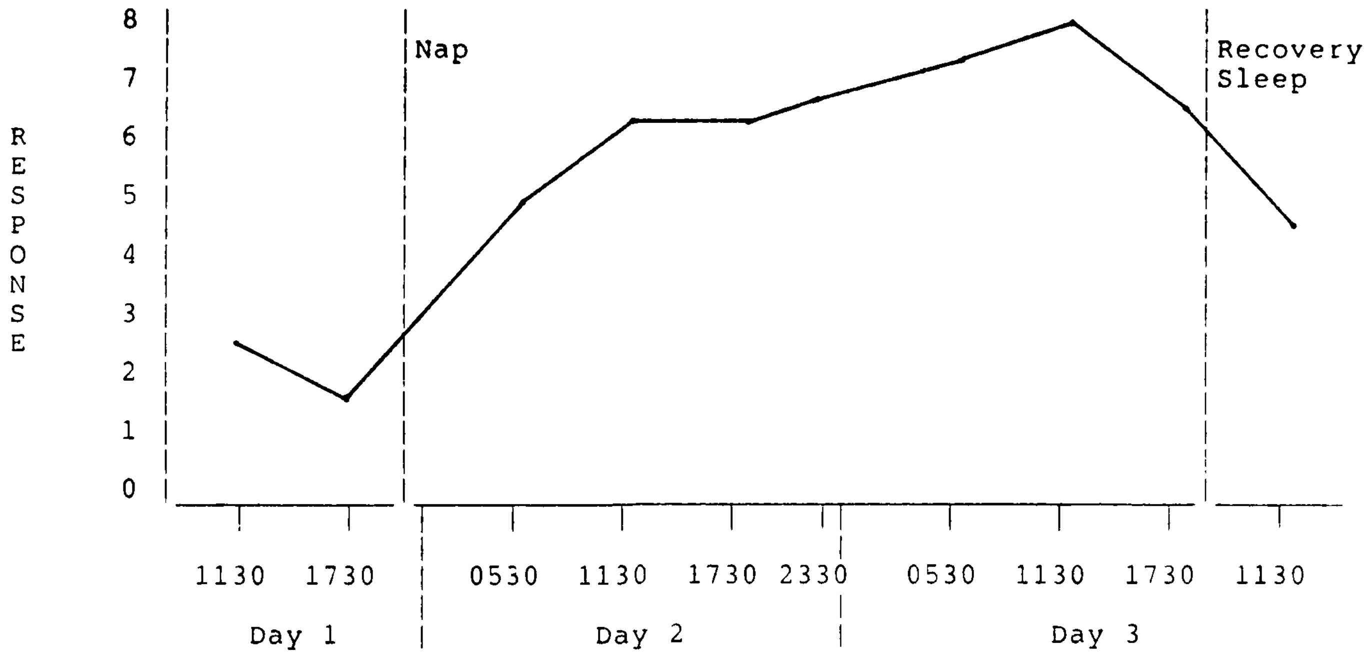


Figure 20. General Information Task

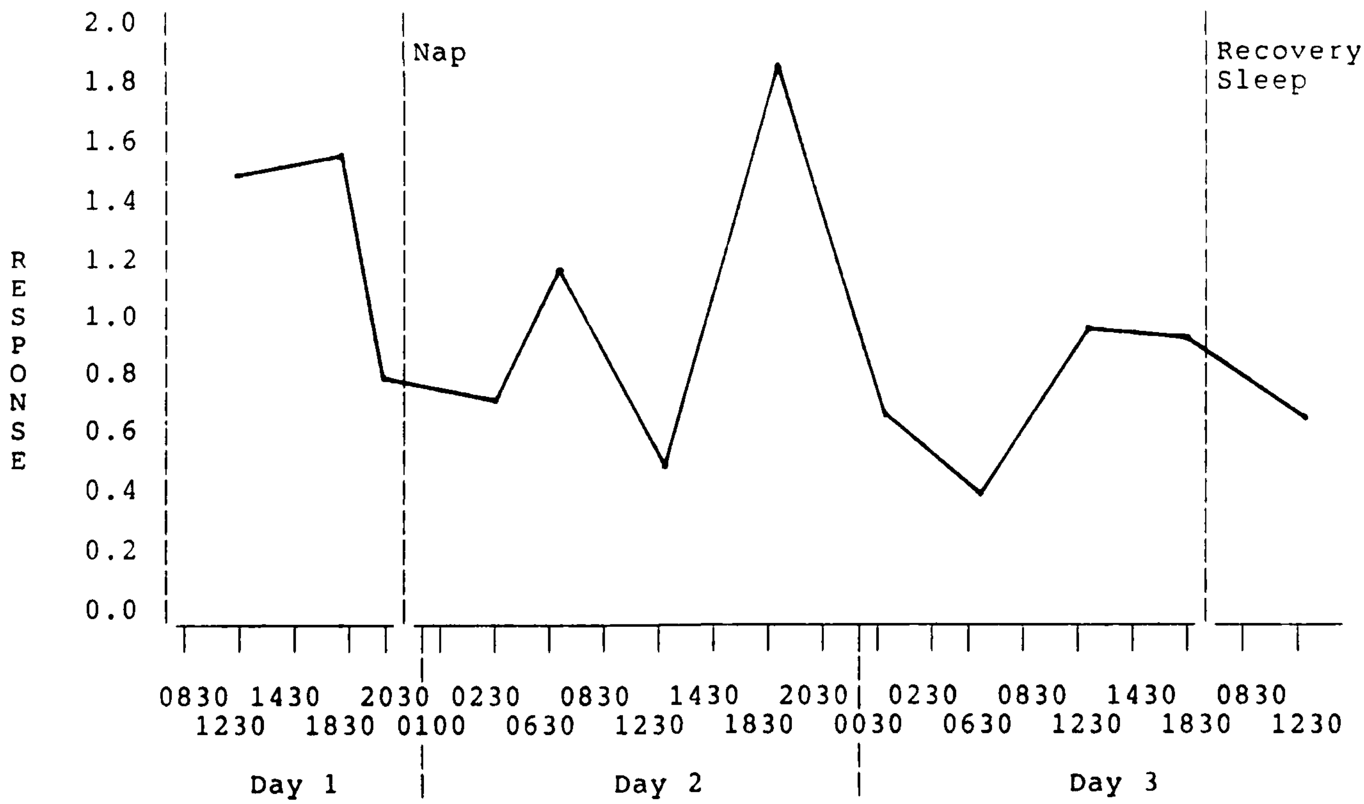


Figure 21. Individual Induction Task

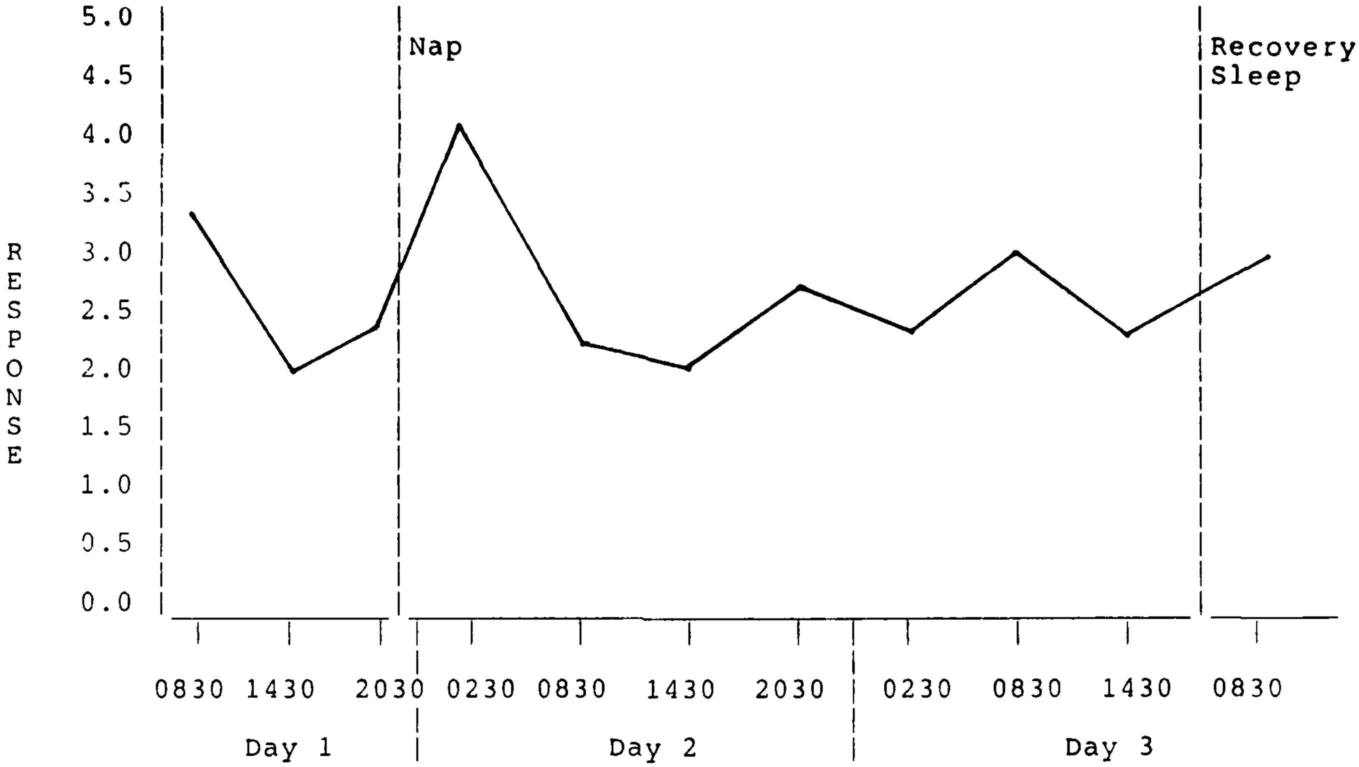
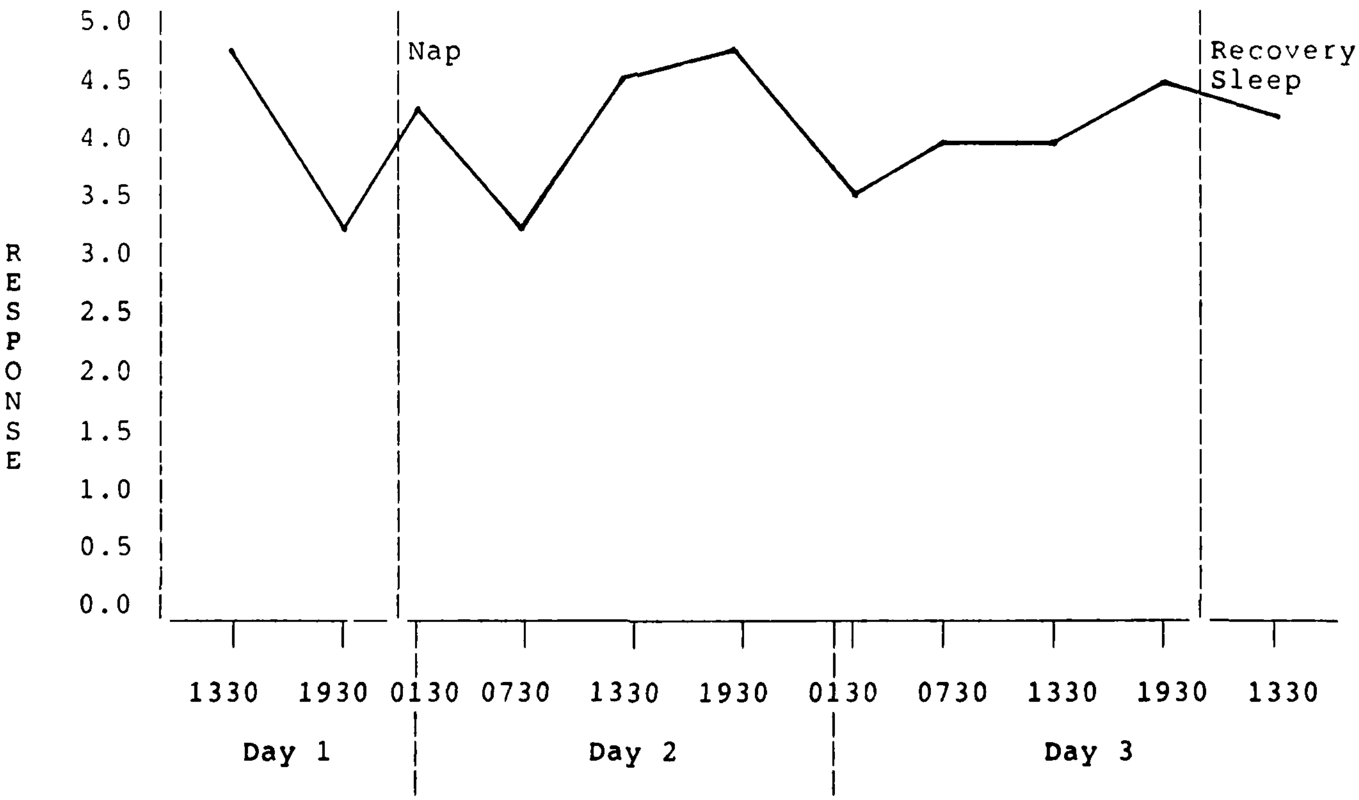


Figure 22. Group Induction Task



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